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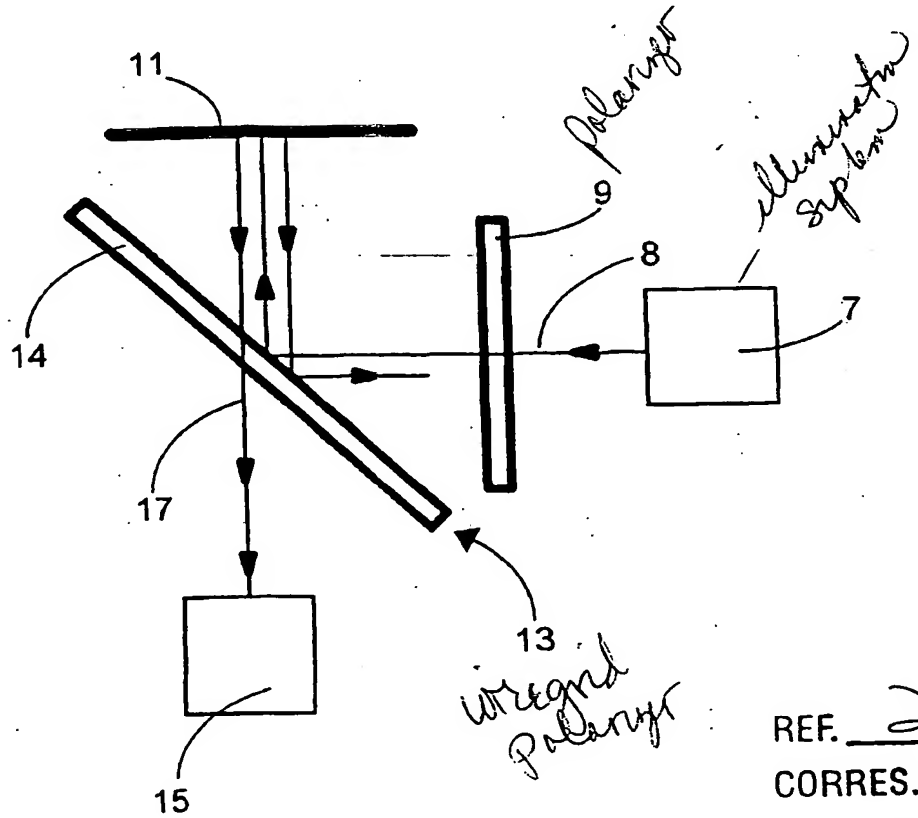
(54) Title: POLARIZATION ARRANGEMENT



(57) Abstract: A tilted polarization splitter (13) for use with a projection lens (15) and a light modulating panel (11) is provided. The polarization splitter has an ultra thin substrate (14) whose thickness is chosen so that the depth of focus of the projection lens in imager space is greater than the astigmatism produced by the splitter at its tilted angle. The polarization splitter can be a wire grid polarizer, polarization coating, or birefringence film carried by or formed on the ultra thin, plane parallel plate substrate.

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POLARIZATION ARRANGEMENT

CROSS REFERENCE TO RELATED PROVISIONAL APPLICATION

This application claims the benefit under 35 USC §119(e) of U.S. Provisional Application No. 60/292,178, filed May 18, 2001, the contents of which are incorporated herein in their entirety.

FIELD OF INVENTION

This invention relates to projection optical devices for use with reflective liquid crystal displays, e.g., LCoSs. More particularly, the invention relates to an arrangement of polarization components designed to work with reflective liquid crystal displays and maintain an effective separation of illuminating light and reflective light.

DESCRIPTION OF PRIOR ART

Reflective liquid crystal displays (e.g., LCoS displays – Liquid Crystal on Silicon displays) work with polarized light in accordance with the following: "off" pixels of the display reflect light without changing its polarization state and "on" pixels rotate the polarization of the illuminating light by 90 degrees. (Alternatively, "on" pixels can leave the polarization unchanged and "off" pixels can rotate the polarization, but the "off" equal no change in polarization and "on" equal a change in polarization is, in practice, the most common approach.) A known optical layout of polarization components is shown in Fig. 1. See Miyatake, U.S. Patent 5,327,270, entitled "Polarizing Beam Splitter Apparatus and Light Valve Image Projection System" which issued on July 5,1994, the content of which is incorporated herein by reference.

In the layout of Fig. 1, illuminating light 8 passes through an initial polarizer 9 (S polarizer) and is reflected from the diagonal of a polarization

modulating panel and the projection lens, said polarization splitter comprising a substrate having a thickness T such that the astigmatism introduced by the substrate at its tilted angle is less than or equal to D.

In addition to the foregoing, during use, the optical system will also include an illumination system, with the tilted polarization splitter being located between the illumination system and the light modulating panel.

Additional features and advantages of the invention are set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the invention as described herein.

It is to be understood that both the foregoing general description and the following detailed description are merely exemplary of the invention, and are intended to provide an overview or framework for understanding the nature and character of the invention as it is claimed.

The accompanying drawings, which are incorporated in and constitute part of the specification, illustrate various aspects of the invention, and together with the description, serve to explain the principles of the invention. It is to be understood, of course, that both the drawings and the description are explanatory only and are not restrictive of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic drawing of a prior art polarization arrangement which employs a polarization beam splitter and a quarter wave plate.

Fig. 2 is a schematic drawing of a polarization arrangement in accordance with the invention which employs a tilted polarization splitter having a substrate which does not generate unacceptable levels of astigmatism.

The reference numbers used in the drawings correspond to the following:

3	PBS
5	quarter wave plate

thickness of the substrate (plane parallel plate) is made very small (e.g., about 0.15 mm). With this thickness the astigmatism is practically negligible.

Table 1 shows the amount of astigmatism induced by various thicknesses of tilted (45 degrees) plane-parallel plates composed of glass. See Smith, Warren J., Modern Optical Engineering: The Design of Optical Systems, 2nd edition, in the Optical and Electro-Optical Engineering Series, Robert E. Fischer and Warren J. Smith, series editors, McGraw-Hill, New York, 1990, page 96-99, and, in particular, page 99, the content of which is incorporated herein by reference.

A typical f-number of a projection lens designed to be used with a LCoS is 2.8. An acceptable (not noticeable) blur at the imager is generally about one pixel and a representative pixel size for a LCoS is 9 microns. Accordingly, a 2.8 f-number corresponds to a depth of focus in imager space of +/-0.025 mm, where imager space is the space between the LCoS and the projection lens, i.e., it is the space where the LCoS is located. See the above W. Smith text at pages 145-148. Because there is no optical power between the LCoS and the projection lens, this depth of focus value applies throughout imager space. The data in Table 1 show that the astigmatism created by a tilted plane-parallel plate with a thickness of 0.15 mm is within this depth of focus, which means that it can be ignored.

It should be noted that a depth of focus of +/-0.025 mm based on pixel size and projection lens f-number is functionally the same as the depth of focus which results from considering the resolution of the human eye (1.5 arc minutes) as defining acceptable blur. In particular, the required depth of focus in imager space for a human eye located approximately 2 meters from a screen upon which a 70X image of a light modulating panel has been projected is approximately +/-0.035 mm, and thus from Table 1, the astigmatism of a substrate having a thickness which is less than or equal to, for example, 0.15 millimeters is again within this depth of focus and can be ignored.

Projection Display, Volume 7, No. 11, July 20, 2001, pages 6-8).

Similarly, the above described ultra thin substrate can be used with a polarization coating instead of a wire grid structure. This configuration has the same benefits (i.e., no astigmatism and low sensitivity to non-flatness and deformation), but still requires a quarter wave plate for compensation of the skew rays' effect. For this embodiment of the invention, the angle of the surface of the polarization coating with respect to the optical axis may differ from 45 degrees to achieve an effective incidence angle for light impinging on the coating. Tilt angles other than 45 degrees can also be used with other polarization separating mechanisms, such as the wire grid polarizers and polarizing birefringence films discussed above.

As another variation, free-raster LCD panels which are addressed directly using light from a CRT can be used in the practice of the invention. Along these same lines, the invention is not intended to be limited to light modulating panels (valves) now known but is intended to include any and all panels which may be developed in the future.

A variety of other modifications which do not depart from the scope and spirit of the invention will be evident to persons of ordinary skill in the art from the disclosure herein. The following claims are intended to cover the specific embodiments set forth herein as well as such modifications, variations, and equivalents.

What is claimed is:

1. An optical system comprising:

(a) a light modulating panel;

(b) a projection lens for forming an image of the light modulating panel, said projection lens having a depth of focus D in imager space; and

(c) a tilted polarization splitter located between the light modulating panel and the projection lens, said polarization splitter comprising a substrate having a thickness T such that the astigmatism introduced by the substrate at its tilted angle is less than or equal to D.

2. The optical system of Claim 1 wherein D is approximately 0.05 millimeters.

3. The optical system of Claim 1 wherein T is approximately 0.15 millimeters.

4. The optical system of Claim 1 wherein the polarization splitter is tilted at an angle of approximately 45°.

5. The optical system of Claim 1 wherein the polarization splitter is a wire grid polarizer.

6. The optical system of Claim 1 wherein the polarization splitter comprises a polarization coating.

7. The optical system of Claim 1 wherein the polarization splitter comprises a polarizing birefringence film.

8. The optical system of Claim 1 wherein the light modulating panel is a reflective liquid crystal display.

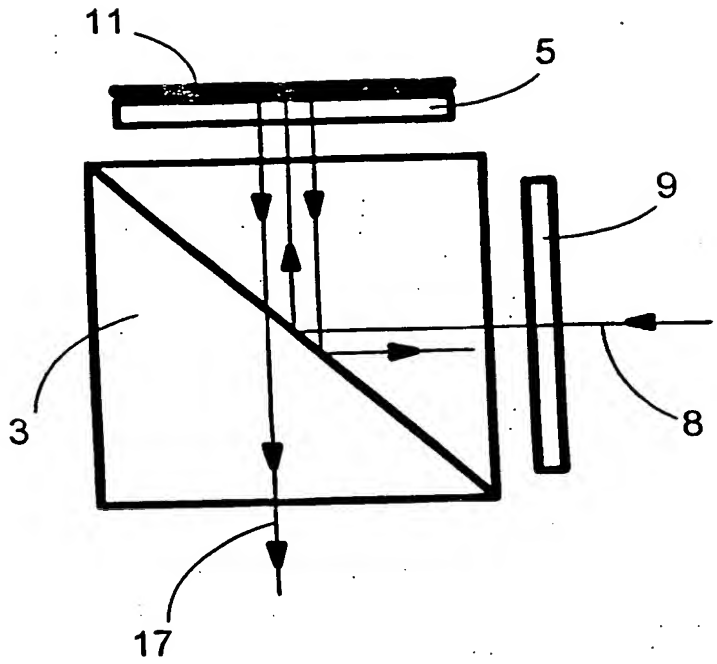
9. The optical system of Claim 1 wherein the light modulating panel is a liquid crystal on silicon panel.

10. An optical system comprising:

(a) an illumination system;

(b) a light modulating panel;

(c) a projection lens for forming an image of the light modulating panel, said projection lens having a depth of focus D in imager space; and



Prior Art

FIG. 1

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G 02 F 1/03
US CL : 359/251, 618, 637, 256, 252, 253, 245, 246, 483, 485, 494

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 359/251, 618, 637, 256, 252, 253, 245, 246, 483, 485, 494

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,400,093 A (TIMMERS) 21 MARCH 1995 (21/03/95) see entire reference.	1-21

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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